Channel coding method for high definition digital television signal

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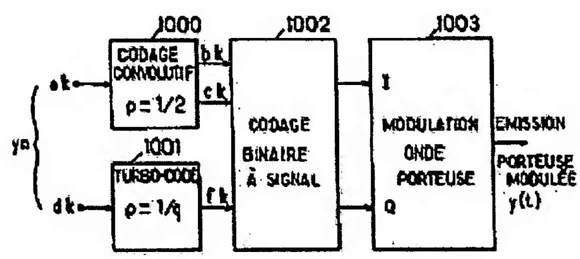
Abstract of **FR2724522**

The method involves coding a first set of conventional binary picture elements (ak) using convolution coding (1000). For each binary element in the first set, a first group of binary elements define a point from four in a first sub-constellation. The argument of the phase corresponds to one of the four phase states of the modulation frequency. A second set of high definition elements are turbo-coded simultaneously in parallel to form a second sub-constellation with phase argument equal to a multiple of half a determined phase value. A carrier wave is phase-modulated (1003) and decoding (2002,2005) the superposition of sub-constellations yields a modulation with 16 phase states corresp. to binary values of both groups.



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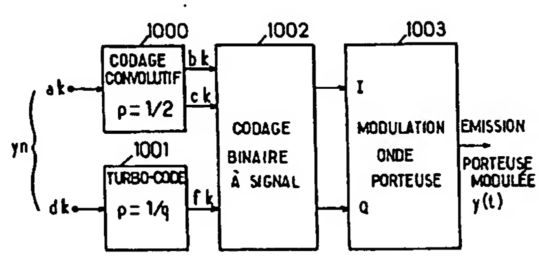
(54) PROCEDE ET DISPOSITIF DE CODAGE-DECODAGE DE CANAL MULTIRESOLUTION EN TELEVISION NUMERIQUE HAUTE DEFINITION ET CONVENTIONNELLE.

(57) L'invention concerne un procédé et un dispositif de codage-décodage de canal multirésolution de télévision HD et conventionnelle.

Les éléments binaires ak d'image conventionnelle sont codés (1000) { bk, ck} pour former une première sous-constellation d'argument de phase Ψk à quatre états de phase et les éléments binaires dk d'image HD sont codés (1001) en au moins un élément binaire fk pour former une deuxième sous-constellation d'argument de phase $\theta k = i\ \theta/2$, $i \in \{m, m\}$ m impair $\neq 0$. Une onde porteuse est modulée en phase (1002, 1003) selon la loi de phase $\phi k = \psi k + \theta k$ selon une constellation complexe superposition des sous-constellation.

Application à la transmission de programme de télévision HD et conventionnelle sur un même canal.



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Ultralow phase noise Ti:sapphire laser rivals 100 MHz crystal oscillator

R. P. Scott, C. Langrock, and B. H. Kolner

I. Introduction

The timing stability of modelocked lasers is an important quantity but is very difficult to measure accurately. This is especially true for Kerr-lens modelocked Ti:sapphire lasers [1] and some harmonically modelocked fiber lasers [2] which demonstrate very low phase noise. We have assembled a system for characterizing the phase noise of modelocked lasers which displays exceptionally high dynamic range (> 170 dB) and accuracy (±2 dB). We have used this system to characterize a femtosecond Ti:sapphire laser and found it to have short term stability close to that of the precision crystal oscillators used in its characterization. This extraordinary result suggests the possibility that modelocked lasers could find applications in high stability RF and microwave sources.

The most informative measurements of timing stability are made in the frequency domain by observing the power spectrum of the sidebands produced when random or discrete noise modulates the phase or frequency of the laser pulse train. There are two approaches to this measurement. In the first, a photodiode directly detects the optical pulse train and feeds the signal to a spectrum analyzer. The sidebands adjacent to any Fourier component can then be related to the rms timing jitter. This "direct technique" is of very limited utility because of the limitations of the spectrum analyzer's dynamic range and it's IF and baseband filters. Furthermore, low frequency Fourier components can have a large amount of AM noise which can obscure the true PM spectrum. Using higher harmonics can reveal more of the phase noise spectrum but this is also limited in accuracy beyond a few harmonics. The phase noise amplitude (not power) grows nonlinearly with harmonic number as the modulation drives the Bessel functions out of their linear range (this seems to be seldom appreciated by practitioners).

A superior method relies on using a high stability reference oscillator which is kept in phase quadrature with respect to the laser under test by a phase-locked loop (phase detector method, Fig. 1). The output of the phase detector is a voltage proportional to the phase deviation between the laser and the reference oscillator. Low frequency FFT and RF spectrum analyzers then measure the spectrum of this phase-demodulated signal with great precision and high dynamic range since the analyzers do not have to handle the high powered carrier. A detailed treatment of this method applied to modelocked lasers can be found in [3].

Clearly, the quality of the phase noise measurement by the phase detector method depends on the spectral purity of the reference oscillator. To date, almost all measurements of modelocked lasers have been made using synthesizers as reference oscillators. The internal reference oscillator of the synthesizer can be pulled, generally, by a few Hertz using electronic frequency control (EFC: voltage tuned varactor across a crystal). However, we have found that the spectral purity of most synthesizers is insufficient to characterize a well constructed and operating Ti:sapphire laser. Indeed, the literature contains frequent evidence of laser phase noise being masked by the reference oscillator [2, 4].

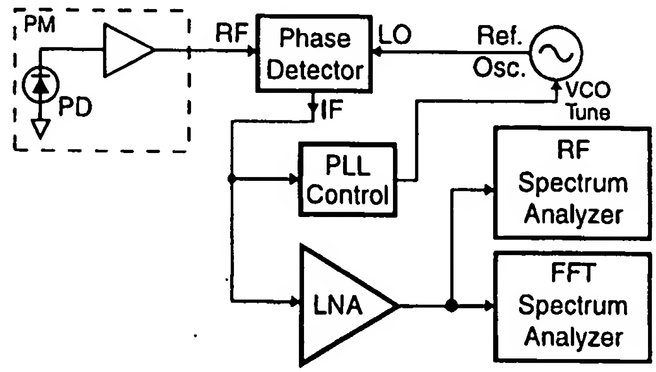

Fig. 1. Typical measurement setup for spectral analysis of laser phase noise. LNA; low noise amplifier, PD; photodiode, LO; local oscillator port, RF; radio frequency port, VCO; voltage controlled oscillator.

II. The Measurements

To overcome the rather high phase noise floor limitations presented by synthesizer references, we have used a very low noise crystal oscillator to characterize our Ti:sapphire laser (K&M Labs Model TS). The oscillator has a fundamental frequency of 100 MHz and a broadband phase noise floor of <-175 dBc/Hz at ≥10 kHz offset frequencies. We used a matched pair of these oscillators to characterize each other and thus establish the lowest phase noise measurable by the system (see Fig. 2, trace 2).

A critical aspect of using any reference oscillator is its ability to track the wandering frequency of the free-running laser. Our laser drifts less than 10 Hz in any 20 minute measurement period. There are also occasional frequency jumps of up to 2 Hz and the oscillator must be able to track these as well. Alternatively, one can phaselock the repetition rate of the laser to a stable source and dramatically reduce the requirements on the reference oscillator. We have tried both approaches and measured approximately the same phase noise spectrum except that within the loop bandwidth (<200 Hz), the phase noise was reduced by about 10 dB.

Figure 2 shows phase noise data from our measurement

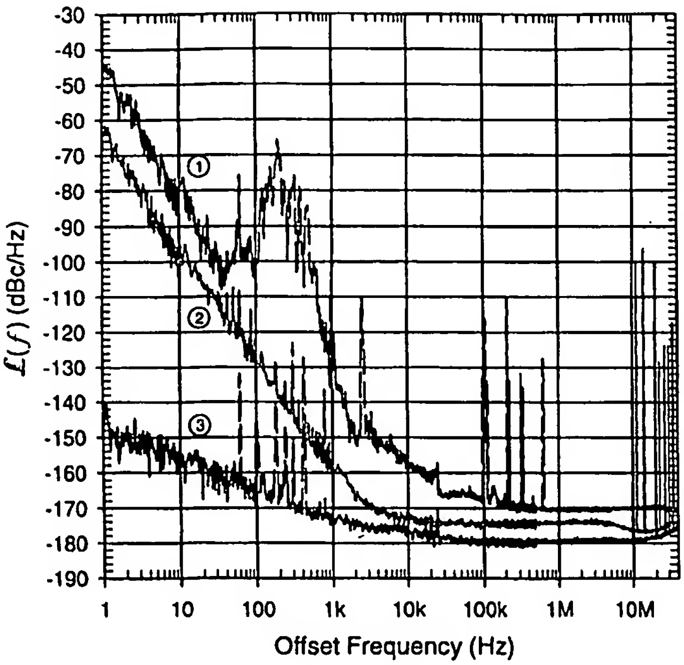

Fig. 2. SSB phase noise as a function of carrier offset frequency. Trace 1: Phase noise of Ti:sapphire laser phaselocked to 100 MHz crystal oscillator (average photocurrent 3.5 mA). Trace 2: Phase noise of two identical 100 MHz crystal oscillators. Trace 3: Measurement system noise floor.

system, a modified HP 3047A. Trace 1 is the phase noise of our Ti:sapphire laser at 100 MHz as measured against a low noise 100 MHz crystal oscillator. Trace 2 is the phase noise of a pair of identical 100 MHz crystal oscillators and trace 3 is the system noise floor established by driving both ports of the phase detector from a common crystal oscillator with bandpass filters and a 90 degree phase difference between the two ports. (All phase noise is thus correlated, simulating a pair of ideal oscillators). The phase noise of the laser is seen to be quite good and close to that of the crystal oscillator except in the audio region from 30 Hz to 20 kHz. Note; no special efforts were made to acoustically isolate the laser from room noise such as fans, flowing water, pumps, etc. We believe that with modest effort, the noise in the audio range could be substantially reduced by improving the phaselocked loop performance and acoustically isolating the laser cavity.

The spur at 2.5 kHz is due to a resonance in the piezoelectric translator used to control the cavity length for phaselocking. The step down in noise at 25 kHz occurs at the transition between the FFT and the analog RF spectrum analyzer. Notice that for the data below 25 kHz, the FFT analyzer is subject to signals which are simultaneously > 80 dB apart. In order to avoid overloading the front end of the analyzer and exceeding the dynamic range of the A/D converter, the instrument downranges to keep the peak at 200 Hz within linear operational limits. Up at 25 kHz, the measured phase noise is actually below the front end noise of the FFT analyzer by a few decibels. Above 25 kHz, the RF spectrum analyzer takes over with a standard mixer-type front end which has greater dynamic range and can measure the weak noise power in the presence of the strong noise signals at low frequencies.

The spurs at multiples of 100 kHz are due to the switching power supply in the diode-pumped solid state laser used to pump the Ti:sapphire laser. And, finally, the spurs above 10 MHz are due to RF sources elsewhere in the building.

If we wish to convert the phase noise data to rms timing jitter, we must integrate the total double-sideband phase noise power spectral density. Since the spectrum of our laser is dropping rapidly from 1 Hz (i.e. the slope= -40 dB/decade), almost all of the timing jitter is contained in the first few Hz of offset frequency. Thus, upon integration, we find that $\Delta t_{rms} = 9.8$ ps. On the other hand, if we start the integration higher in frequency, say from 1 kHz to 40 MHz, we find that $\Delta t_{rms} = 53$ fs. Thus, timing jitter is seen to be a matter of perspective.

The data indicate that fairly ordinary Kerr-lens modelocked lasers have the potential to rival high stability crystal oscillators in terms of short term frequency stability (phase noise). Long term drift can be easily controlled by phaselocking to a primary or secondary frequency standard. This suggests that designing lasers with "technical noise" considerations in mind may lead to applications in high purity RF/microwave sources [5].

In conclusion, we have demonstrated remarkably low phase noise from a conventional Kerr-lens modelocked Ti:sapphire laser using a carefully assembled and characterized phase noise system. The ultimate phase noise floor of -170 dBc/Hz is, we believe, the lowest laser phase noise reported to date, and approaches that of high performance 100 MHz crystal oscillators.

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